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# White Pine Blister Rust in Northern Idaho and Western Montana: Alternatives for Integrated Management

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## PREFACE

Western white pine management has undergone dramatic change since the introduction of white pine blister rust. This report summarizes major events and presents current technology for foresters managing stands in the western white pine type of Idaho and Montana. Site-specific management alternatives are developed through the use of a dichotomous key. Supporting information is provided in a series of subject appendixes. We discuss the concept of Rust Hazard and its application to stand management. Approaches to using rust resistance and intermediate stand treatments are explained. Regardless of stand management intensity, this information should provide insight into both the influence of white pine blister rust on stands and the effects of stand and site manipulation on the disease.

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## INTRODUCTION

Western white pine (*Pinus monticola* Dougl. ex D. Don.) was once the most sought after conifer species in the Western United States, particularly in Idaho and western Montana (Davis 1942). The major impetus for settlement of the Clearwater region of Idaho was provided by the valuable white pine forests. Many past and present forest products companies in Idaho and Montana owe their beginnings to white pine. The lumber is soft, white, and easily worked, making it useful for a wide variety of wood products. Silvical characteristics that add to its popularity are its fast growth rate, good form, and potentially greater optimum stocking density than associated conifers (Watt 1960). To this day, stumpage values tend to be higher for western white pine than associated conifers (Manning and Howe 1983). With the exception of white pine blister rust, white pine is less susceptible to damage by insects and diseases than are other conifers.

Unfortunately, management of western white pine has been confounded by the introduction of the fungal disease white pine blister rust, caused by *Cronartium ribicola* Fisch. This disease was introduced into Western North America from Europe in 1910 on infected eastern white pine seedlings grown in France and planted near Vancouver, BC. Western white pine proved to be highly susceptible to blister rust, with mortality rates of 90 percent or more in what were once vigorous, well-stocked stands.

## History of Control Efforts

White pine blister rust requires an alternate host, currant or gooseberry (*Ribes* spp.), to complete its life cycle.

*Ribes* are associated with western white pine throughout its range. Early attempts to halt spread of the disease were aimed at breaking the disease cycle by eradicating the alternate host from within and around valuable white pine stands. This approach had been successful in reducing infection in the Lake States (King and others 1960). Eradication work began in the Northern Region in 1924 and continued until 1966.

In 1966 and 1967, the Northern Region of the Forest Service, U.S. Department of Agriculture, conducted surveys to evaluate the effectiveness of *Ribes* population reduction in controlling pine infection (Carlson and Toko 1968). Results demonstrated that *Ribes* density could not be sufficiently lowered by pulling or spraying plants. In many cases, *Ribes* populations were reduced from thousands per acre to as few as several bushes per acre after numerous treatments. Nevertheless, when only a few bushes remained proportions of pines infected in the stands were not significantly reduced. These findings are consistent with experience in the Lake States. King (1958) reported that "study results indicate that beyond relatively few bushes per acre, *Ribes* population has little effect on fatal blister rust infection." The conclusion was that *Ribes* eradication was not economically feasible in the Northern Rocky Mountains (Ketcham and others 1968).

From about 1957 until 1966, attempts also were made to control the disease by treating infected stands with antibiotics. It was hoped that this type of treatment might eliminate existing infections and immunize the trees against further infection, at least for a period of time (Moss and others 1960). Antibiotics were difficult and expensive to apply, and results were erratic (Dimond 1966). As a result, this type of control effort also was largely discontinued after 1966.

Forest Service stand management policy regarding western white pine included three major changes as of 1966 (Ketcham and others 1968): (1) planting of western white pine was discontinued on an operational basis, (2) thinning and weeding would favor species other than western white pine, and (3) salvage of merchantable western white pine damaged by blister rust or bark beetles was accelerated. This was in conjunction with the cessation of *Ribes* eradication efforts and curtailment of antibiotic use for direct blister rust control. White pine was being temporarily abandoned in timber management. Time was needed to develop rust-resistant pine, a program that was under way and appeared promising.

## Disease Resistance

As early as 1933, pathologists noticed that even in the most heavily infected stands, a few individual white pines could be found that were free of the rust and apparently resistant to the disease. It was not until 1949 that research was initiated to determine if genetic resistance did

in fact exist in western white pine (Bingham and others 1953). The results of these early experiments demonstrated that resistance to blister rust does exist in natural stands and that this resistance can be passed on to progeny under controlled conditions. As a result, the cooperative resistance breeding program became operational in USDA Forest Service, Intermountain Station and Northern Region in 1957 (Bingham and others 1973).

It was nearly 15 years before seed was operationally available from this first generation of selectively bred rust-resistant trees ($F_1$). Seedlings from the second generation ($F_2$) are now being outplanted. Demand for the seed is increasing. Seedlings of these seed sources placed in test plantations are surviving even better than predicted (Bingham and others 1973).

Unfortunately, genetic resistance to blister rust is not infallible because the fungus may genetically overcome host resistance (Kinloch 1982). Strains of *C. ribicola* capable of overcoming resistance in the pine host have been discovered recently in Oregon (McDonald and others 1984) and Japan (Yokota 1983).

## Integrated Management

The alternatives presented here are based on four major goals for western white pine management: (1) reduce probability of pine infection, (2) reduce pine mortality following infection, (3) maintain genetic diversity of white pine for silvical characteristics in addition to rust resistance, and (4) minimize selection pressure on the rust.

Pine infection can be reduced through use of rust-resistant pine and by minimizing *Ribes* populations. Mortality of infected pine can be reduced through intermediate treatment such as pruning and canker excision. Genetic diversity of white pine can be maintained through an aggressive program of selection and testing of new candidate rust-resistant trees and through judicious use of lower levels of rust resistance. Selection pressure on the fungus can be minimized by conservative use of highly rust-resistant pine stock.

The rust and its hosts maintain an intimate and dynamic genetic association. Experience from agricultural crops such as wheat and wheat rust diseases has shown that a limited host gene pool results in natural selection for rust genotypes that allow the fungi to overcome host resistance. Precautions against undue selection pressure on the rust are only prudent. Genetic diversity and economical production of western white pine timber can be obtained through matching levels of resistance with levels of rust hazard. Rust hazard is defined as "the favorableness of the particular site for the development of the rust" (Stillinger 1943).

Intermediate stand treatments, such as pruning, can further enhance genetic diversity because lower levels of host resistance can be successful on sites with higher rust hazard through these intensive management procedures (Brown 1972; Hunt 1982; Nicholls and Anderson 1977; Weber 1964). Advanced natural regeneration and numerous plantations of nonselected (for blister rust resistance) stock are now of an age at which intermediate treatments will make the difference between bringing a considerable portion of the white pine through to a commercial product or starting over.

The factors to be considered in managing western white pine as a stand component can be confusing, causing significant options or influences to be overlooked. This report identifies some of these options and influences to aid in developing comprehensive site-specific management plans.

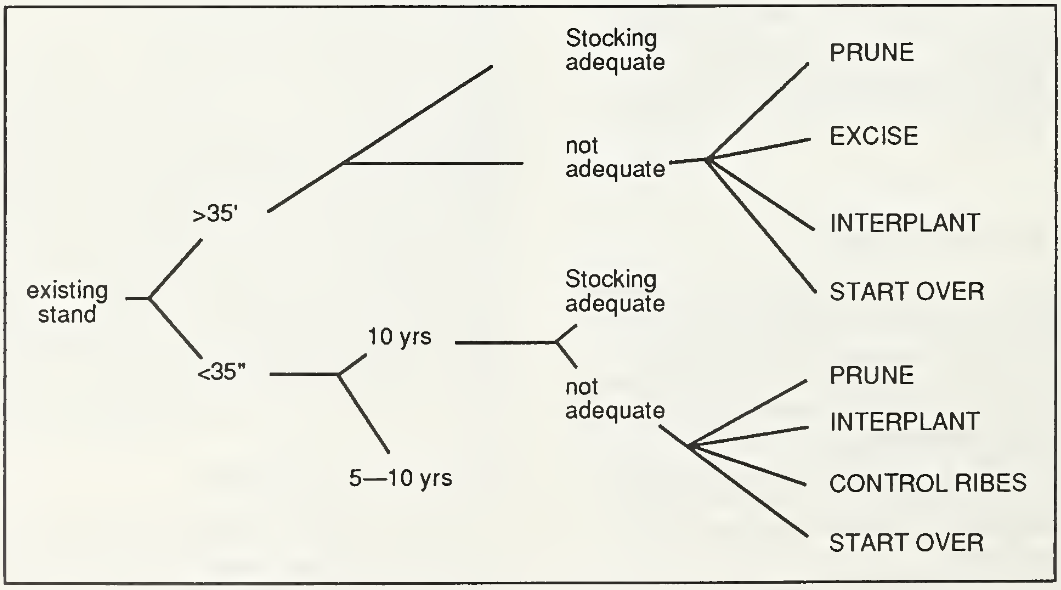


Figure 1—Decision key for managing existing stands.

## MANAGEMENT ALTERNATIVES

Our intention is not to prescribe treatments, but rather to stimulate thought and to provide further information to aid in decision making. Alternatives are presented that relate to specific stand or site characteristics. Managers must decide which alternatives are operationally and economically viable for their own situation. We have tried to summarize the voluminous information regarding management of white pine in the presence of blister rust into a format that simplifies interpretation.

Alternatives are presented in a dichotomous key format, beginning with general information. The first pair in this key appears as:

1. Sites to be regenerated. . .
   1'. Existing stands to be managed. . .

If the stand fits the latter, a series of questions will attempt to typify the stand to lead to a set of alternatives for that stand. The next major division is based on average stand height (fig. 1). If the stand is taller than 35 feet, only existing infections are likely to result in mortality. Stands that average less than 35 feet in height are subject to death due to both existing and future infections.

In setting height limits for stand separation, the assumption is that white pine will seldom be found as a significantly all-aged stand due to requirements for seedbed and sunlight.

The first alternatives considered try to obtain adequate stocking with existing stands. Destruction of the stand or interplanting among acceptable crop trees, creating an uneven-aged stand, are considered to be "last ditch" efforts when the existing stand cannot be treated economically to retain adequate stocking.

Specific information on how rust hazard is measured, how rust status data are taken, characteristics of genetically improved stock, how to thin and prune, and other related information is presented in appendixes. Appendixes that pertain specifically to items in the decision key are noted in parentheses.

If the site is to be regenerated but has not yet been cut, options that may lessen rust hazard are suggested. For example, a shelterwood method of regeneration may be considered with the goal of reducing viability of *Ribes* seed stored on the site.

The other major section of the key deals with use of blister rust-resistant white pine to regenerate sites. Based on the rust hazard, white pine seedlings of a variety of genetic derivations are considered for regeneration. White pine seedling types, ranging from wild, natural regeneration to rust-resistant planting stock, are matched to five levels of rust hazard (fig. 2).

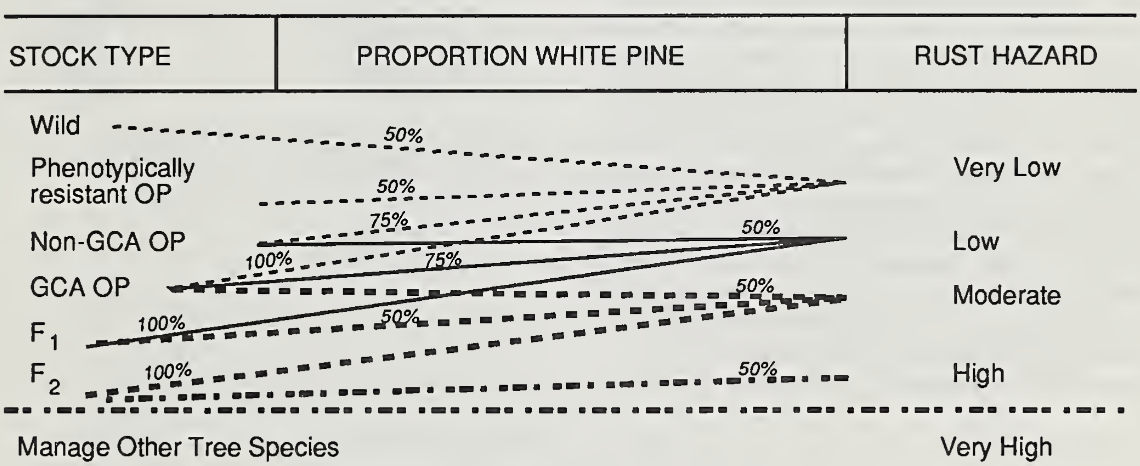


**Figure 2**—Key for matching western white pine stock types to rust hazard. Percentages are recommended western white pine component of stands. OP = open pollinated; GCA = general combining ability; $F_1$ = GCA x GCA; $F_2$ = $F_1$ x $F_1$. refer to appendix F for further explanation of stock type. Refer to appendix B for explanation of rust hazard.

Planting stock recommendations also are based on the relative proportions of white pine to be planted in stands. Greater white pine components result in higher risk of loss to blister rust. Therefore, stock types with higher levels of resistance are recommended as white pine proportions are increased. Economic advantages of managing for higher proportions of white pine in stands may justify the greater risk on some sites as demonstrated by Manning and Howe (1983). They reported an economic analysis of reforesting with blister rust-resistant white pine in combinations with other commercial conifer species. Using existing stands on the Wallace Ranger District, Idaho Panhandle National Forests, as a basis, they compared projected stands reforested with planted $F_1$, $F_2$, and wild, natural western white pine. A Stand Prognosis Model developed by Wykoff and others (1982) was used to simulate development of fictitious and existing sapling stands to culmination of mean annual increment.

Results of this analysis indicated that increasing the proportion of white pine on north-facing slopes from 39 percent (with wild stock) to 68 percent (with $F_2$ stock) could increase discounted revenues from $265.86/acre to $1,106.23/acre. Douglas-fir, grand fir, and western hemlock were the other primary components of the stands on north-facing slopes. Greater white pine components were also economically advantageous in simulated stands on south-facing slopes but less so than on north-facing slopes.

Discounted revenue increases for stands with larger white pine components were attributed to increased yield because of faster growth, better form, and higher stumpage prices of white pine compared with other species. On south slopes, however, ponderosa pine is nearly as good as western white pine in growth, form, and stumpage prices.

Height growth of western white pine is better than that of Douglas-fir in 30-year-old stands on sites with white pine site index 80, while the inverse is true for site index 40 (Deitschman and Green 1965). Planting purely white pine should only be considered for sites with especially high white pine growth indices (appendix A) and very low to moderate rust hazard (appendix B). Managing for pure stands of any species also may be subject to agency policy. Therefore, stock type recommendations in the decision key are presented for (1) mixed species stands and (2) pure western white pine stands.

## COMPUTER PROGRAMS

Computer programs are available that calculate the rust index and 40-year mortality predictions based on rust status. They are housed at the USDA Forest Service National Computer Center in Fort Collins, CO.

Data entry is simplified by a program that queries the user for the correct input. The program constructs a header card containing pertinent information such as user name, agency, location, stand designation and location, and so forth. The user is then asked whether the rust index program or rust status program is to be run. The next series of questions will construct the appropriate array for the rust index (table 1) or rust status (appendix D) using the data input.

Assistance in obtaining access and directions for utilizing the programs is available for Federal agencies through USDA Forest Service, Northern Region, Cooperative Forestry and Pest Management. For State and private agencies in Washington, Idaho, and Montana, assistance is obtained through the State Department of Lands, Forestry Division, pest management specialists. Copies of programs with brief explanation of construction are available also from these sources.

**Table 1**—Rust hazard estimation from rust index values

| Index value | Rust hazard level[1] |
|---|---|
| <0.00005 | 1 very low |
| 0.00005-0.00499 | 2 low |
| 0.00500-0.09999 | 3 moderate |
| 0.1000-1.00000 | 4 high |
| >1.00000 | 5 very high |

[1]Hazard levels apply only to wild-type white pines.

## KEY TO ALTERNATIVES

1 Sites to be regenerated ........................................ 30

Refers to sites with mature stands that will be removed for regeneration, and sites where stands have already been removed but still need regeneration.

1' Existing stands to be managed ........................................ 2

Generally refers to immature stands that may receive intermediate treatments, although in some cases mature stands also may be treated where stand removal is not the goal.

2(1') White pine is an important component (A) ........................................ 4

This decision is left to the manager. Species composition, value of western white pine present, and condition of alternative species in the stand are important considerations. Treatment of white pine is unlikely to be economical if it is not an important component in the stand.

2'(1') White pine is not an important component ........................................ 3

3(2') Site is suitable for white pine (A), consider managing to reduce *Ribes* populations (G) ........................................ End

If white pine is not presently an important component, but the site is suited for growing white pine, efforts could be made to avoid increasing or to reduce *Ribes* populations so that the rust hazard does not increase.

3'(2') Site is not suitable for white pine ........................................ End

If the site is not suited to growing white pine, management could proceed without specific regard to *Ribes*.

4(2) Stand averages less than 35 feet in height ........................................ 18

4'(2) Stand averages more than 35 feet in height ........................................ 5

Trees more than 35 feet in height are too tall for accurate canker counts, which are necessary to calculate the rust index. Rust status information is more important in this size class. Some of the trees in these stands may be merchantable or approaching merchantability, which could significantly alter management opportunities.

5(4') Trees are not of sufficient size to support commercial thin or salvage ........................................ 11

5'(4') Trees are of sufficient size to support commercial thin or salvage ........................................ 6

6(5) Stand is overstocked ........................................ 8

6'(5) Stand is not overstocked ........................................ 7

7(6') Insignificant volume loss expected due to mortality within 20 years or before scheduled harvest (D) — **No Intermediate Treatment Suggested** ........................................ End

7'(6') Significant volume loss expected due to mortality within 20 years or before scheduled harvest (D) — **Consider Salvage of High-Risk White Pine or Shortened Rotation of Stand** ........................................ End

8(6) Stand will not be overstocked in 20 years according to projected mortality from rust status survey (D) ........................................ 7

8'(6) Stand will be overstocked in 20 years according to projected mortality from rust status survey (D) ........................................ 9

9(8') Expected blister rust mortality from rust status survey is insufficient to accomplish desired stocking (A, C, D) — **Consider Thinning** ........ End

Moderate high thinning removing 30 to 40 percent of the basal area for sawlog volume production also may reduce potential rust hazard through *Ribes* management (G).

9'(8') Expected blister rust mortality from rust status survey is sufficient to accomplish desired stocking (A, C, D) ........ 10

10(9') **Consider Allowing Blister Rust to Accomplish Thinning**

If (1) sufficient white pine are expected to die to achieve the desired stocking level, and (2) they will die early enough to avoid significant growth reduction in the stand due to overstocking, it may be more economical to allow blister rust mortality to accomplish the stocking reduction.

10'(9') **Consider Thinning; Removing High-Risk White Pine**

Moderate high thinning removing 30 to 40 percent of the basal area, or light selection thinning removing about 20 percent of the basal area, has produced best results for sawlog production (C). Moderate high thinning may have the additional benefit of reducing *Ribes* population potential (G).

11(5) Stand is not currently adequately stocked ........ 15

Judgment should be based on site, species, and "normal" attrition in the absence of blister rust and on management objectives. The influence of blister rust infections on currently living trees is considered in key pair 12 for stands otherwise adequately stocked.

11'(5) Stand is currently adequately stocked ........ 12

12(11') Stand will not be adequately stocked in 20 years based on rust status (D) ........ 14

If, after application of rust status data, the stand is not expected to be adequately stocked in 20 years, rehabilitation options will be tested.

12'(11') Stand will be adequately stocked in 20 years based on rust status (D) ........ 13

After application of rust status data, the stand is expected to retain sufficient stocking in 20 years. The stand may require thinning.

13(12') Stand will not be sufficiently overstocked to result in significant growth loss before commercial thinning size is achieved — **Consider Deferring Treatment** ........ End

If stocking is appropriate for the stand age considering mortality projected in key item 12', action can probably be deferred in this stand.

13'(12') Stand will be sufficiently overstocked to result in significant growth loss before commercial thinning size is achieved — **Consider Thinning** (A, G) ........ End

Few new lethal infections are likely to be produced in trees this size.

Overstocked stands of this age probably have few *Ribes* bushes remaining so revitalization of *Ribes* plants is not a concern. But, rust hazard for the site could be greatly increased by burning thinning slash thus causing *Ribes* seed to germinate. This increase in hazard would likely carry through into the next rotation. Abundant seed would be deposited before crown closure created sufficient shade to kill the *Ribes* plants.

14(12) Stand rehabilitation will give adequate stocking in 20 years based on rust status (D) ........ 17

Rust status survey will give an estimate of survival and treatment opportunities. Both pruning and canker excision are considered together in this key pair.

14'(12) Stand rehabilitation will not give adequate stocking in 20 years based on rust status (D) ........ 15

You may decide to harvest the existing stand or rehabilitate some of the present stand and interplant to attain full stocking.

15(11)(14') Start over (F) ........ 32

If stand is greatly understocked, you may find it more economical to harvest any merchantable trees and regenerate than to allow the site to remain understocked. You are directed to key pair 32 for regeneration stock type selection. Slash treatment may significantly alter rust hazard (B, G).

15'(11)(14') Interplant (F) ........ 16

Western white pine (A) and other species may be planted beneath an understocked overstory allowing survivors of the present stand to reach merchantability while the site is being regenerated.

16(15') Rehabilitate white pine (E) ........ 32

This may include pruning alone or both pruning and excising to bring many of the present trees to merchantability. Results of the rust status analysis should aid in deciding whether, and by what means, to rehabilitate. You are referred to pair 32 for white pine stock selection.

16'(15') Do not rehabilitate white pine ........ 32

You may find it most feasible to retain any trees from the present stand that survive without treatment until they are merchantable. You are referred to pair 32 for white pine stock selection.

17(14) Pruning branch cankers will give adequate stocking in 20 years (D) — **Consider Pruning** (E) ..... End

If pruning will allow you to carry sufficient stocking to merchantability (which may be sooner than 20 years), this procedure may be economically feasible.

17'(14) Pruning branch cankers will not give adequate stocking in 20 years — **Consider Both Pruning and Excising** (E) ........ End

Having passed to this pair through key item 14, rust status survey data have shown that pruning and excising together are required to retain adequate stocking. Although this branch of the key terminates with the alternative to prune and excise, you should examine the situation carefully before deciding to do so. If expected residual stocking of all desirable tree species, after mortality, approaches adequate stocking, it is probably not economically feasible to prune or excise cankers. Stand rehabilitation is biologically feasible and potentially most economically feasible in this size class of trees.

18(4) Mean stand age of white pine is greater than 10 years. ........ 23

18'(4) Average stand age of white pine is 5 to 10 years ........ 19

From key item 4, stands are separated based on usefulness of the rust index to estimate rust hazard and on reasonable management options for the respective age groups.

19(18') Less than 10 percent infected (D)—check again at age 15 to 20 years ........ End

This is a sufficiently low level of infection for blister rust to be of minor concern at present. The stand should be checked again at age 15 to 20 years to see if the situation has changed.

19'(18') More than 10 percent infected ........ 20

If this infection exceeds 10 percent, you should take a closer look to decide if some timely action could reduce losses.

20(19') Stand will be adequately stocked in 10 years (D) ........ End

Ten years is about as long a period as can be reasonably predicted based on the percent-infected data collected in this young age class. Stand should be checked again at 15 to 20 years of age to make a more accurate prediction of survival.

20'(19') Stand will not be adequately stocked in 10 years ........ 21

Pruning and rust hazard reduction (through *Ribes* population reduction) are explored for stocking maintenance.

21(20') Stand would be adequately stocked by pruning (D) — **Consider Pruning** (E) ........ End

Particularly if unusually high infection rate resulted from a "wave-year" phenomenon, and most cankers are presently in a prunable condition, this may be an excellent opportunity to save a stand. *Ribes* population reduction may be applied as needed to protect the pruning investment (B, G).

21'(20') Stand would not be adequately stocked by pruning ........ 22

If adequate stocking cannot be retained, it may be increased through interplanting or removal of the present stand and regeneration of better-suited stock.

22(21') Interplanting with resistant white pine or other species is considered ........ 32

Resistant white pine may be planted if rust hazard level is 4 or lower. *Ribes* population reduction may be applied to reduce the hazard and improve survival of residual white pine (B, G).

22'(21') Removal of stand and site regeneration is considered ........ 32

If infection rates are too high to treat the stand to retain adequate stocking (or if you decide not to treat), it may be better to start over with only 5 to 10 years invested in the stand than to carry a poorly stocked stand to rotation age. Resistant white pine and/or other tree species may be regenerated.

23(18') Stand not adequately stocked in 20 years according to rust status (D) ........ 25

Judgment whether the stocking is adequate, as projected in 20 years from rust status data, should be based on site, species mix, "normal" attrition in the absence of blister rust, and management objectives.

23'(18') Stand adequately stocked in 20 years according to rust status (D) ........ 24

24(23') Stand not overstocked — **Consider Deferring Treatment** ........ End

If the stand will be adequately stocked in 20 years and it is not currently overstocked, there is no need for action now.

24'(23') Stand overstocked — **Consider Thinning** ........ End

If rust hazard level (B) is 1 (very low), it is unlikely that stocking reduction will greatly increase infection frequency. If rust hazard exceeds this level, however, stocking reduction can result in dramatic increases in infection frequencies. In this case, thinning or other activities resulting in reduced stocking should be delayed to 25 to 30 years of age (C). Pruning may also be applied with thinning to limit increases in lethal infections (C). Slash treatment may affect rust hazard (G).

25(23) Adequate stocking can be achieved in 20 years by pruning (D) — **Consider Pruning** (E) .............. End

If results of a rust status survey indicate that a sufficient number of trees can be saved by pruning, you may find it economical to do so.

25'(23) Adequate stocking cannot be achieved in 20 years by pruning .................................................. 26

If rust status survey shows that too few trees can be saved by pruning, you may be able to reduce *Ribes* populations as well as prune and thereby achieve adequate stocking.

26(25') Adequate stocking can be achieved by pruning and *Ribes* population reduction (D) — **Consider Pruning** (E) **and Reducing *Ribes* Populations** (G) .................................................. End

By the combined effects of pruning to reduce current infection rates, and *Ribes* population reduction to reduce future infection rates, you may be able to retain adequate stocking.

26'(25') Adequate stocking cannot be achieved by pruning and *Ribes* population reduction .................................................. 27

If too many infections have reached stems for pruning and *Ribes* population reduction to sufficiently reduce mortality rates, some stands may be economically excised as well. This is particularly true for stands with marginal stocking with a large proportion of trees savable by excision.

27(26') Adequate stocking may be achieved by pruning, excising (D), and *Ribes* control (F) — **Consider Pruning, Excising, and Reducing *Ribes* Populations** (E, G) .................................. End

Whenever excising is done, pruning should be done in conjunction. The *Ribes* population should be considered in deciding whether to treat the stand. Large *Ribes* populations may place the pruning and excising investment in jeopardy. *Ribes* population reduction may be feasible if populations exceed 25 bushes per acre (B, G).

27'(26') Adequate stocking cannot be achieved by pruning, excising, and *Ribes* population reduction (D) ...... 28

Alternatives to achieve adequate stocking by replacing the stand or interplanting are considered.

28(27') Starting over is considered (F) .................................................. 32

Current stand would be slashed and site prepared for planting or natural seeding.

28'(27') Interplanting with rust-resistant white pine or other species is considered (F) .................................................. 29

If sufficient numbers of trees will be retained with or without treatment, you may opt to hold all or a portion of the current stand while interplanting to increase stocking.

29(28') Pruning, excising and/or reducing *Ribes* population is considered (E, G) ............................................ 32

You have already explored the feasibility of these intermediate treatments. You may still find that pruning, pruning with excising, or *Ribes* population reduction will increase survival of residuals. Effects of *Ribes* population reduction on the fate of interplanted white pine should be examined as well.

29'(28') Pruning, excising and/or reducing *Ribes* population is not considered (E, G) .................................... 32

If you decide not to treat the current stand nor reduce *Ribes* populations, you may want to proceed to item 32 in the key for selection of white pine stock if you plan to interplant with white pine.

30(1) Site not suitable for white pine (A) — **Consider Regenerating to Other Species** ........................................ End

Site suitability is based on properties of the site and silvical characteristics of western white pine as summarized in appendix A.

30'(1) Site suitable for white pine .................................................................. 31

This key pair begins the second major grouping. Sites that are to be regenerated are treated here to select proper levels of resistance of white pine stock to match the site rust hazard.

31(30') Planned for cutting ..................................................................................... 42

If the stand has not yet been cut, there may be opportunities to keep rust hazard lower by modifying harvest and site preparation methods.

31'(30') Already clearcut ......................................................................................... 32

This also assumes site preparation has been completed.

32(15)(16)(16')(22)(22')(28)(29)(29')(31')(44')(49) rust hazard level greater than 1 (B) ......................... 35

This is a major converging point in the key. When a recommendation for planting stock is wanted, you are directed to this key pair.

Stock type recommendations: These items treat stock recommendations for increasingly hazardous sites. Recommendations for mixing rates such as "Regenerate up to 75 percent $F_1$ means that white pine should make up no more than 75 percent of the stand composition at the time of stand establishment and that the resistance level should be equal to that of $F_1$ stock as explained in appendix F. This does not imply that the final stand at rotation age will contain 75 percent white pine. Attrition rate of white pine is expected to be greater than that of other species. Refer to appendix F for explanation of stock type abbreviations.

32'(15)(16)(16')(22)(22')(28)(29)(29')(31') rust hazard level 1 (B)..................................... 33

33(32')(43) Pure stand of white pine: **Regenerate GCA OP or $F_1$** ............................................ End

33'(32')(43) Mixed species stand ............................................................................... 34

34(33) **NonGCA OP; up to 75 Percent** (F) ............................................ End

34'(33) **Wild Type; to Less than 50 Percent** (F) ....................................... End

35(32) Rust hazard level greater than 2 ............................................................. 38

35'(32) Rust hazard level 2 .................................................................................. 36

36(35')(46) Pure stands of white pine: Regenerate **$F_1$ OR $F_2$** (F) ......................................... End

36'(35')(46) Mixed species stands ............................................................................ 33

37(36') **GCA OP; up to 75 Percent** (F) ........ End

37'(36') **NonGCA OP; up to 50 Percent White Pine** (F) ........ End

38(35)(50) Rust hazard level greater than 3 ........ 41

38'(35)(50) Rust hazard level 3 ........ 39

39(38')(48) Pure stands of white pine: **Regenerate $F_2$** (F) ........ End

39'(38')(48) Mixed species stands ........ 40

40(39') **$F_1$; up to 50 Percent of Stand** (F) ........ End

40'(39') **GCA OP; up to 50 Percent of Stand** (F) ........ End

41(38) Rust hazard level 5: **Consider Regenerating Species Other Than White Pine or Reducing *Ribes* Populations** (G) ........ End

41'(38) Rust hazard level 4: **Regenerate Up to 50 Percent with (52) $F_2$** ........ End

42(31) Rust hazard level (B) greater than 1 ........ 45

Rust hazard level information may be useful both for white pine stock selection and to help in deciding whether harvest or site preparation methods may be altered to avoid actuating potential *Ribes* populations.

42'(31) Rust hazard level 1 ........ 43

It may be particularly desirable to use white pine seed trees on these sites to aid in maintaining genetic diversity of white pine.

43(42') Clearcut regeneration method is considered ........ 33

If clearcutting is considered, you are referred to the key section (item 33) on white pine planting stock selection. This does not preclude natural regeneration on the clearcut site if the rust hazard is very low; item 34' recommends that less than 50 percent of a stand be wild type white pine. This is to ensure proper stand closure to shade out *Ribes* and prevent prolonged exposure of white pine in the stand to heavy rust inoculum loads.

43'(42') Other regeneration methods are considered ........ 44

Very low hazard sites such as these provide many options for management that would raise the prospects for severe infection on higher hazard sites (C, H).

44(43')(46')(50') Natural regeneration is considered ........ End

If natural regeneration methods are used, the resistance level of white pine in the regeneration stand will be approximately equal to that of the tested wild-type (see appendix F) stock. You can probably manage white pine as somewhat less than 50 percent of the stand and still attain at least 50 percent stand closure at 20 years of age. With higher rust hazard levels or larger proportions of white pine, you are less assured of success. Intermediate treatments such as pruning or *Ribes* population reduction may still make the white pine manageable in these stands. The cost of more intensive management may not be justifiable when compared to planting costs for establishment of a rust-resistant stand.

44'(43')(46')(50') Regeneration by planting is considered ........ 32

If the site is to be planted, you are referred to key pair 32 for selection of white pine planting stock.

45(42) Rust hazard level greater than 2 .......... 47

45'(42) Rust hazard level 2 .......... 46

46(45') Clearcutting method is considered .......... 36

46'(45') Other silvicultural methods are considered .......... 44

Considerations are presented in key pair 44.

47(45) Rust hazard level greater than 3 .......... 51

47'(45) Rust hazard level 3 .......... 48

48(47') Clearcutting method is considered .......... 39

At this hazard level, natural regeneration to include white pine is not recommended.

48'(47') Other silvicultural methods are considered .......... 49

Modification of harvest methods can reduce actuated *Ribes* populations well below the estimated potential.

49(48')(52')(53') Low disturbance logging method (G) .......... 32

Logging on snow can result in actual *Ribes* population 95 percent lower than potential population due to nongermination and subsequent inactivation of *Ribes* seed. See appendix G for discussion. Rust hazard level should be reassessed following logging to determine white pine stock type for regeneration.

49'(48')(52')(53') Three-step shelterwood method .......... 50

This silvicultural method may significantly reduce site hazard by stimulating *Ribes* germination and subsequently shading out *Ribes* plants before much seed deposition has occurred. Refer to appendix G for discussion.

50(49') More than one *Ribes* per acre 3 to 10 years after first cut (H) .......... 35

*Ribes* seed germination should be near maximum about 3 years following site preparation (or cutting if there was no site preparation). Up to about 10 years following germination, *Ribes* populations generally remain stable. After this time, *Ribes* populations should begin to decline as crown closure reduces ground irradiation. If after the first cut, *Ribes* populations are still too high for natural regeneration of white pine, white pine seed trees should not be used. If a white pine component is desired, rust-resistant white pine could be planted.

50'(49') Less than one *Ribes* per acre 3 to 10 years after first cut (H) .......... 44

If *Ribes* peak populations are less than one per acre, you may opt to regenerate wild-type white pine using the shelterwood system. Wild-type white pine regeneration should not exceed 50 percent of the stand when established.

51(47) Rust hazard level 5 .......... 53

Silvicultural methods that reduce germination and survival of *Ribes* may lower the rust hazard sufficiently to manage resistant white pine.

51'(47) Rust hazard level 4 .......... 52

52(51') Stand is to be clearcut .......... 41

Clearcutting, particularly with broadcast burning, will not lower the rust hazard.

52'(51') Other silvicultural methods to be used .......... 49

With this high rust hazard level, alternative harvest and site preparation methods could be considered to reduce actual hazard.

53(51) Stand is to be clearcut. **Consider Regenerating Species Other Than White Pine or Administering Post Harvest *Ribes* Population Reduction** (H) .......... End

This level of rust hazard exceeds limits for even the most resistant white pine stock available. Consider managing species other than white pine on these sites unless *Ribes* populations are reduced.

53'(51) Other silvicultural practices are considered .......... 49

Alternative harvest and site preparation methods could significantly reduce the blister rust hazard on these sites.

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**Figure 4**—(A) Zone of tree crown in which new infections have most potential to reach the stem (highest probability of lethality). One- and 2-year-old needles are less than 24 inches away from the stem. (B) Basal stem canker. This canker is girdling about 50 percent of the circumference of the stem. Diameter of the stem is measured at point of greatest girdle (broken line) for rust status data collection. (C) Stem canker. This canker is girdling about 40 percent of the circumference of the stem. Diameter of the stem is measured at point of greatest girdle (broken line) for rust status data collection.


**Figure 4** (Con.)—(D) Excision of a stem canker. A tree scribe is used to cut a channel through the cambium at 1 inch beyond the visible margin of the canker. (E) Margin of stem canker. The visible margin of this canker (arrow) includes a band of discolored bark well beyond the obviously dead bark. (F) Margin of stem canker. The visible edge of this canker (arrow) is close to the obviously dead bark.



**Figure 5**—(A) Branch canker measurement. When collecting rust status data, measure the length of branch from the nearest margin of the canker (CE) to the stem. Measure stem diameter immediately above the whorl (SD). (B) *Ribes* and common species easily confused with *Ribes*—(a) *Rubus parviflorus,* thimbleberry; (b) *Ribes viscosissimum,* sticky currant; (c) *Ribes lacustre*, prickly currant; (d) *Rubus idaeus*, red raspberry.

**Figure 5** (Con.)—(C) *Ribes lacustre*. (D) *Ribes viscosissimum*.

## APPENDIX A: WESTERN WHITE PINE SILVICS

Several reviews of western white pine silvics and silviculture have been published (Fowells 1965; Graham and others 1984; Wellner 1962, 1973). The species has received a great deal of research, and much is known about its silvical characteristics and culture. It grows in climates typified by short, dry growing seasons and heavy winter snowfall (Fowells 1965; Wellner 1962). Western white pine grows equally well on a great variety of soil types (Ferrell 1955); however, soil moisture is an important limiting factor. Growth is best on deep, well-drained, medium- to fine-textured soils with high water-holding capacity (Copeland 1956, 1958).

In Idaho and Montana, western white pine grows between 2,000 and 6,000 feet above sea level. The best stands are found in wide river bottoms; gentle lower slopes and northerly slopes; and in gently rolling country of the Priest, Coeur d'Alene, St. Joe, and Clearwater River basins (Fowells 1965).

Fire has left its mark at some time or other on practically every acre of western white pine forests (Haig and others 1941). Western white pine is a fire species and owes it prevalence mainly to fires that have destroyed stands and allowed white pine to become established. Among its associates, western white pine is rated intermediate in fire resistance (Flint 1925).

Populations of western white pine in the Rocky Mountains, Northern Cascades, and northern coastal areas are notably uniform and appear to be genetically differentiated from populations in the Sierra Nevada (Rehfeldt and others 1984). Transition zone populations from the central and south Cascades were intermediate in character between the northern and southern groups of populations. Within the northern and southern groups, geographic patterns of variation were weak and elevational patterns were not found. Variation within populations and families was large. Most variation within northern Idaho populations probably is due to phenotypic plasticity rather than genetic differentiation (Rehfeldt and others 1984).

Western white pine occurs as a major seral in six phases within the hemlock series and one phase within the subalpine fir series in northern Idaho. In addition, it occurs as a minor seral on 22 of 65 phases of grand fir, western redcedar, western hemlock, and subalpine fir series identified by Cooper and others (1987) for northern Idaho.

In western Montana it occurs as a major seral in the *Clintonia uniflora* phase, *C. uniflora* habitat type of western hemlock, and in some areas of subalpine fir—*Clintonia uniflora, Aralia nudicaulis* phase (Pfister and others 1977). As a minor seral in Montana, western white pine was recognized by Pfister and others in 14 phases in grand fir, western redcedar, western hemlock, and subalpine fir series.

Western white pine is about equal in shade tolerance to Douglas-fir. It is more tolerant than western larch and lodgepole pine and less tolerant than Engelmann spruce, grand fir, western hemlock, and western redcedar (Baker 1949).

## Regeneration

Both natural and artificial regeneration of western white pine have high success rates. Mineral soil, burned or unburned, is better than duff surfaces for seed germination and for planted seedling establishment (Wellner 1962).

Western white pines produce mature cones in the field as early as age 10. Although monoecious, trees remain predominantly female until about age 20 (Bingham and others 1972). Trees tend to be consistent in their ability to produce cones and set seeds (Bingham and Rehfeldt 1970). Long-term yields for 25- to 75-year-old trees average 28 cones with 100 filled seed per wind-pollinated cone. Yields vary among mother trees, localities, and seed years. Cone crop cycles are generally 3 to 4 years between major yields (Bingham and Rehfeldt 1970).

Seed dispersal is effective up to about 400 feet from parent trees. Seedling establishment is favored by partial shade on severe to moderately severe sites. On the more sheltered sites, such as north slopes, light shade to full sun is best for seedling establishment (Haig and others 1941). Factors contributing to seedling mortality were discussed by Haig (1936) and Haig and others (1941).

Regeneration methods silviculturally favorable to seedling establishment include clearcutting, seed tree methods, and shelterwoods. Western white pine seedlings require 30 to 40 percent of full sunlight for establishment (Wellner 1962). Once well established, western white pine grows best on all sites in full sunlight (Haig and others 1941). Shade of any amount favors its more tolerant associates.

Overwood densities of 15 to 40 trees per acre were recommended by Graham and others (1984) for shelterwood regeneration methods in the western white pine type. Four to six seed trees per acre were considered sufficient for seed tree methods in this type.

When seed tree or shelterwood regeneration methods are employed, seed trees should be removed within about 20 to 30 years to avoid suppressing growth of white pine regeneration (Moss and Wellner 1953).

Western white pine seedlings grow slowly at first. Dominant seedlings growing in the open require about 8 years to reach a height of 4.5 feet on excellent sites and about 16 years on poor sites. Once established, they increase rapidly in height growth (Wellner 1962). By age 20, the height of the average dominant white pine on excellent sites is about 16 feet and on the poorest sites about 10 feet (Haig 1932).

## Intermediate Stands

Dominance and stand composition are determined during the period between seedling establishment and about 30 years of age. They change little thereafter unless intermediate treatments are imposed (Watt 1960).

Mixed-species stands in the white pine type often have naturally high stocking densities. Number of trees per acre on sites with a 50-year site index of 40 are listed by Haig (1932) as 11,500 at age 20, 3,020 at age 60, and 980 at age 120. On excellent sites, index 80, trees per acre

were 2,050 at age 20, 540 at age 60, and 235 at age 120. At these stocking densities trees are generally small. For example, on good sites (index 60) at age 120, trees averaged 12.2 inches d.b.h. In these stands, 60 percent of the trees were under 13 inches d.b.h. and 27 percent were under 7 inches d.b.h.

Western white pine is slow to respond to thinning, particularly beyond about 30 years of age (Deitschman 1966). It grows equally well over a range of stocking densities, so it can be managed with a heavy residual stocking of 400 to 500 trees per acre following thinning at 20 to 25 years of age (Graham 1983). If the stand is not significantly heavier stocked than this prior to thinning, little growth response occurs.

Wellner and Boyd (1960) found diameter growth response following thinning in mature stands to depend largely on tree vigor.

Western white pine is slow to shed lower branches, even in dense stands (Rapraeger 1939). Branches are retained 27 to 73 years (Paul 1938), with small branches persisting as long or longer than do large-diameter branches. Pruning can greatly improve the quality of western white pine wood if performed at about 20 to 30 years of age. But in the Western States pruning is rarely done because it is not considered cost effective where wood quality improvement is the major goal.

Current and potential blister rust status and hazard are important considerations in thinnings, prunings, and regeneration operations. Refer to appendixes B, C, D, E, and F for more information on these.

## Growth and Production

Although western white pine starts slow, by about 40 years of age it will outgrow Douglas-fir and western larch on good to excellent sites (Watt 1960). At 70 years on good white pine sites, larch often begins to drop out of stands due to competition, and Douglas-fir begins to decline due to root disease (Watt 1960). Western white pine retains its advantage until about 120 to 140 years when the more tolerant species gain in position (Watt 1960). Cubic foot increment of western white pine stands culminates at about 100 to 120 years (Davis 1942). According to Haig (1932), 90-year-old western white pines can be expected to average 9.3 inches d.b.h. and 73 feet in height on site index 40 (50-year base). At site index 80, they average 18.3 inches and 145 feet.

A contemporary discussion of economics of managing western white pine on contrasting sites is presented by Manning and Howe (1983). Greater stocking density and more rapid growth compared to associated conifers contribute to the desirability of growing white pine, especially on good white pine sites.

## Diseases, Insects, and Animal Pests

Western white pine has few important diseases. In Idaho and Montana, blister rust is generally the most damaging of these. But in some stands root disease caused by *Armillaria* spp., stem decay caused by *Phellinus pini*, or needle blight caused by *Dothistroma pini* var. *linearis* (Evans 1984; Shaw and Leaphart 1960) may have more impact than blister rust. Other less frequent root diseases, such as *Inonotus tomentosus, Heterobasidion annosum*, and *Phaeolus schweinitzii* may be locally important, (Hubert 1950); *Phaeolus schweinitzii, H. annosum*, and *Phellinus* weirii can cause considerable cull from butt rot.

Root disease caused by *Armillaria* spp. is second to blister rust as a disease of western white pine. *Armillaria* can kill large numbers of trees, particularly saplings, in localized areas. Observations suggest that most *Armillaria*-caused mortality of western white pine occurs between 15 and 30 years of age. This is in contrast to Douglas-fir or true firs, which continue to decline throughout the rotation. Morrison (1981) ranks western white pine as moderately susceptible to *Armillaria* in parts of British Columbia adjacent to Idaho and Montana.

Western white pine is often a preferred species for culture on *P. weirii*-infested sites in northern Idaho and western Montana where Douglas-fir and true firs are severely affected (Smith and Sheldon 1984).

*Atropellis pinicola* stem cankers occasionally cause some loss in form or mortality.

Considerable mortality of first-season germlings may result from damping-off fungi, particularly *Fusarium* spp. (Haig and others 1941). *Pythium* spp. may also be important in damping-off containerized seedlings (James 1985).

Western white pine is not a primary host for any dwarf mistletoe species. Occasional crossover of *Arceuthobium laricis* from western larch or *A. americanum* from lodgepole pine occurs.

Western white pine has few serious insect pests. Mountain pine beetle is important in old-growth stands, killing trees larger than 10 inches d.b.h. It is unlikely to be a major problem in stands managed on rotations shorter than 100 to 120 years.

Seed production from western white pine may be seriously reduced by mountain pine cone beetles (*Conophthorus monticolae*). Localized populations have virtually eliminated harvestable seed in orchards in some years (Dewey and Jenkins 1982). Similar impacts have been reported in natural stands (Barnes and others 1962).

Animals occasionally do serious damage to western white pine. Seedlings are girdled or severed by pocket gophers and rabbits. Seedlings may be heavily browsed by deer and elk, particularly in winter range areas. Porcupines and tree squirrels occasionally girdle saplings or tops of pole-sized trees, and bear clawing can be locally important, causing stem scarring (Molnar and McMinn 1960).

# APPENDIX B: RUST HAZARD

## Infection Intensity

Stillinger (1943) studied the relationship between various factors and rate of increase in blister rust infections in stands. In conclusion he stated, "The rate at which the rust increases is the resultant of all the factors on a particular site which may have any influence upon the increase of the rust infection. For this reason it may be used as an index to the favorableness of the particular site for the development of the rust as well as a guide to the effectiveness of control in relation to the *Ribes* population." Stillinger used "cankers per tree" as his measure of rust increase. Unfortunately, this measure does not account for changes in leaf area (target area) as trees grow. The rate of infection per unit leaf area may remain constant or even decline, while the rate of accumulation of cankers per tree increases.

Buchanan (1938) counted the numbers of needles on young western white pines of a variety of sizes. Infection rates were then expressed by Buchanan and Kimmey (1938) as cankers per 1 million needles to give a more accurate measure of rust intensification in stands.

McDonald and others (1981) took this method a step further by developing a model for pine target using tree height to estimate numbers of needles. Combining this with tree age, they calculated annual target for a given tree. This provided an index to rust infection rate based on cankers per thousand needles per year.

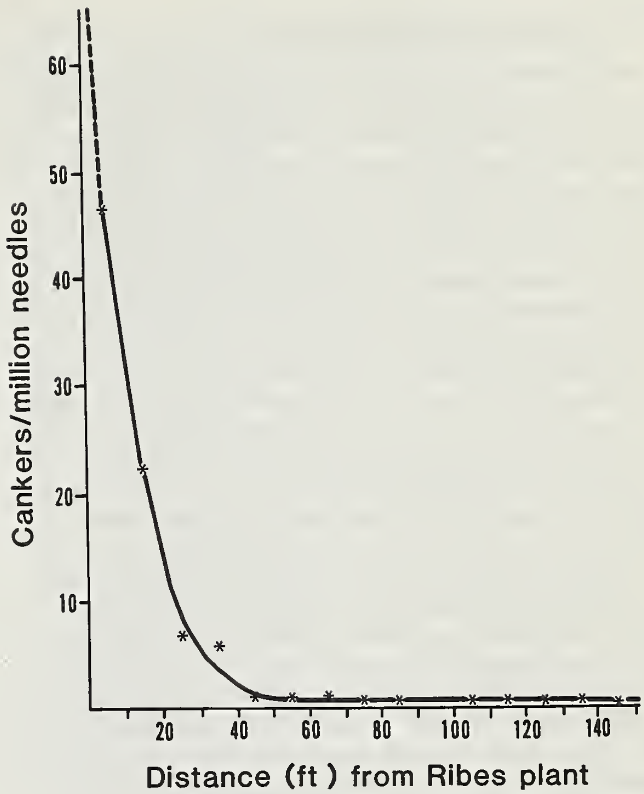


**Figure 3**—Average number of cankers per million needles on 4,600 western white pine saplings within 10-foot concentric zones around infected *Ribes* plants. Redrawn from Buchanan and Kimmey (1938).

## *Ribes* Influence

Number and size of *Ribes* and number of trees per acre were found by Stillinger (1943) to account for 51 percent of the variation in rate of infection (as cankers per tree). Of this, number of trees had little influence, and *Ribes* bush size showed no direct correlation with rate of infection. Thus, the number of *Ribes* bushes per acre accounted for most of 51 percent of the infection rate differences expressed as cankers per tree.

Trees growing nearest to *Ribes* bushes have been shown to bear proportionally greater numbers of cankers. In a study reported by Buchanan and Kimmey (1938) within concentric zones of 0 to 50 feet and 50 to 100 feet from a *Ribes* bush, 0.49 and 0.08 canker per tree was produced respectively in a 2-year period. Stillinger (1943) presented similar data in which 20-year-old trees within 20 feet of an isolated *Ribes* plant had an average of 31 cankers, while trees 61 to 80 feet from the same *Ribes* plant averaged only one canker. Buchanan and Kimmey (1938) demonstrated that the intensity of infection fell to an almost negligible value between 50 and 60 feet from the *Ribes* bush, irrespective of the intensity nearer the bush (fig. 3).

A lethal canker is one which caused or has a high probability of causing a tree to die. Likelihood of lethal infection increases as numbers of cankers increase. Stillinger reported that 84 percent of the trees within 20 feet of a *Ribes* bush were infected and all of these had lethal infections. At 61 to 80 feet from the bush, however, 46 percent were infected, with only 13 percent lethally infected.

The influence of *Ribes* populations is especially important in young stands, up to age 20 or 30 years—the stage at which they are most vulnerable. During these years much of the foliage of a tree is within the zone in which infection is most likely to lead to death of the tree. An infection occurring in a needle more than 24 inches from the bole has a very small chance of reaching the bole. Among circumstances which lead to nonlethal infections, the majority of such cases involve cankers occurring too distal on a branch to reach the bole before girdling and killing the branch, or before the branch dies naturally from insufficient light, or before inactivation of the canker occurs (Hungerford 1977; Kimmey 1969). White pine needles seldom survive more than 4 years (Buchnan 1938), so infections in 3-year-old needles rarely produce cankers (McDonald and others 1981). A zone of foliage from the top of the tree down to where the 1- and 2-year-old needles are more than 2 feet from the bole will account for most of the lethal infections occurring at any point in time (fig. 4A, center of book). This zone changes position as the tree grows. As the tree crown enlarges, proportionally fewer infections occur within this zone.

## Rust Hazard Estimation

Rust infection intensity can vary considerably from one stand to the next (Goddard and others 1985; McDonald 1979). Local weather patterns (Van Arsdel and others 1959) and onsite *Ribes* populations (Moss and Wellner 1953) are generally most responsible for this variation. Occasionally, peculiar air currents have been shown to carry rust spores from concentrated *Ribes* populations to distant white pine stands. Lloyd (1959) reported such a situation occurring in a northern Idaho stand. *Ribes* had been eradicated from the site, and yet the 20-year-old white pine plantation was incurring many new infections. Airflow patterns were studied, revealing that rust spores were carried over a ridge via warm air movement upward from a lake. Noting that blister rust sporidia seldom are carried more than 900 feet from *Ribes* plants to pines, Lloyd concluded that the peculiar air currents created by the lake accounted for the unexpected infection.

Stillinger (1943) defined rust hazard as "the favorableness of the particular site for the development of the rust." Local weather patterns, *Ribes* populations, and occasional unusual air currents such as were studied by Lloyd are the major factors contributing to rust hazard.

Rust hazard estimates are best made on the basis of the rust index (cankers per thousand needles per year) calculated from at least 10 years' accumulation of infections in a stand with white pines less than 35 feet tall.

General ranges of rust indices are used to define rust hazard levels 1 through 5 (table 1).

Rust hazard estimates from *Ribes* populations are less reliable than those based on rust index and should be restricted to use for planting stock selection where an index is unattainable. Only the rust index is sufficiently sensitive for rust hazard estimates to develop management plans for existing stands of white pine.

## Measuring Rust Index

One hundred trees that are at least 10 years of age but less than 35 feet in height are sampled in each stand. Height, number of whorls, and number of rust cankers are recorded for each tree (table 2). The rust index computer program calculates the index and 20-year mortality predictions.

**Table 2**—Rust index data suggested format

| Tree No. | Height | No. whorls | No. cankers |
|---|---|---|---|
| | *Feet* | | |
| 1 | 7.5 | 12 | 3 |
| 2 | 9.3 | 19 | 0 |
| 3 | 8.7 | 15 | 0 |
| 4 | 12.9 | 11 | 1 |
| 5 | 10.1 | 20 | 6 |
| ⋮ | | | |
| 100 | 9.7 | 15 | 10 |

Rust index is a sensitive measure of rust hazard. It provides the best basis for stock type selection to regenerate a site. Rust index also provides a future infection rate estimate for the rust status program mortality model (appendix D). This, with other rust status data, projects mortality rates of white pine stands for up to 40 years hence.

## Rust Hazard Estimated From *Ribes* Populations

If stands meeting the requirements for rust index measurement are not available on or near the site, measurement of *Ribes* populations (appendix H) often will provide an adequate estimate of rust hazard for regeneration stock type selection.

Many sites support naturally low *Ribes* populations, less than one bush per acre (USDA 1950). Much of the infection in stands on these sites is the result of long-distance spread (greater than 1,000 feet from *Ribes* bushes). Infection intensities on these sites are generally low. Wild-type (appendix F) western white pines may be managed as a component of mixed stands on these sites, although with less assurance of survival than white pines with higher levels of resistance. Less certainty of success using wild-type white pines should be weighed against potentially lower cost and greater flexibility of the natural regeneration methods possible with wild-type stock.

As onsite *Ribes* populations increase, their relative influence on infection intensity increases. Spores spreading from local bushes account for an increasingly greater proportion of the infection in the pine stand.

Compared with infection intensities and mortality on a variety of sites, onsite *Ribes* populations are associated with rust hazard levels as presented in table 3.

These *Ribes* population/rust hazard level relationships were estimated on the basis of considerable data from northern Idaho and western Montana stands collected by the Forest Pest Control unit of the Northern Region, USDA Forest Service, in the mid-1960's and from numerous smaller surveys and studies conducted by the Intermountain Research Station, USDA Forest Service.

Appendix H provides an explanation of methods for measuring *Ribes* populations.

**Table 3**—Rust hazard estimation from onsite *Ribes* population

| *Ribes* per acre | Rust hazard level |
|---|---|
| <1 | 1 very low |
| 1-24 | 2 low |
| 25-99 | 3 moderate |
| 100-1,000 | 4 high |
| >1,000 | 5 very high |

# APPENDIX C: STOCKING REDUCTION

## Precommercial Stands

Stocking control often will be necessary to optimize merchantable volume production. Since most naturally occurring stands in the white pine type will be overstocked when young, the first stocking reduction will often be precommercial at age 20 to 30.

Low thinning is currently the method most often used for precommercial thinning in the white pine type. Dominant and codominant trees are released by removing trees in the lower crown classes. Timing of precommercial thinnings may affect blister rust infection rates. Of key interest in our area is a report published by Hungerford and others (1982). Increased lethal cankering rates resulted from precommercial thinning of predominantly white pine stands. The stands were low thinned to 436 and 222 trees per acre when they were 10 to 20 years of age. Infection frequencies of thinned stands surpassed those of unthinned stands in the ensuing 5 years. Stands that had been both pruned and thinned had infection frequencies similar to control stands that were neither pruned nor thinned. Citing the need for a hazard rating system as the basis, they suggested that precommercial thinning in white pine stands be confined to stands with obviously low infection levels.

Increases in lethal infection rates following thinning are likely to be greater on high-hazard sites than on low-hazard sites (Hungerford and others 1982). Delaying thinning to 25 or 30 years of age may somewhat ameliorate the lethal infection increase effect of thinning in three ways: (1) stand diameters of white pines will be larger, improving the chances they will reach merchantability before being girdled by new cankers; (2) the trees may have fewer live branches in their lower crowns where most infections would normally occur; and (3) greater stand closure may have caused more of the shade-intolerant *Ribes* plants to die out.

Current lethal infection rates and rust hazard (appendix B) are important considerations in deciding when and how to accomplish a precommercial thinning.

In general, the better the site quality, the sooner competition becomes a limiting factor for white pine growth.

Graham (1983) suggested that white pine stands are most beneficially thinned between 20 and 25 years of age with respect to individual crop tree diameter growth. He recommended residual stocking densities of 400 to 500 trees per acre at this age. Hungerford and others (1982) recommended delaying thinning of predominantly white pine stands to approximately 25 to 30 years of age to allow time for rust selection pressure on white pine.

Deitschman and Pfister (1973) compared cleanings that favored western white pine and western redcedar at ages ranging from 8 to 16 years. Initial stocking in the mixed-species stands ranged from 21,000 trees per acre in an 8-year-old stand to 7,000 in a 16-year-old stand. Stocking was 3,500 to 1,600 trees per acre following the cleanings.

Deitchman and Pfister evaluated these treatments for meeting the goals of increasing proportion of white pine and western redcedar in the dominant and codominant crown classes and of increasing height and diameter growth. Ingrowth of western hemlock, grand fir, and western larch interfered with these goals somewhat, particularly in stands cleaned at an early age. White pine responded well and maintained its height advantage in all cleaned stands with the exception of an 8-year-old stand which had been moderately cleaned. Here, although white pine growth response was good, western larch remained an important competitor, outgrowing some of the white pines. White pine nearly completely dropped out of the uncleaned stand where western larch and lodgepole pine were strong competitors.

Where grand fir and western hemlock were primary competitors, white pine maintained nearly equal growth with these species until about 30 years of age after which it began decreasing in position.

Removal of grand fir and western hemlock overstory (which had been creating 75 percent shade conditions) and cleaning of the established regeneration to favor western white pine at age 15 resulted in significant gains in white pine growth. Average height of dominant and codominant white pines at age 45 was nearly 60 feet in treated plots compared with 15 feet in the unreleased, uncleaned plots. Moss and Wellner (1953) recommended releasing young white pine stands from overwood by age 20 to 30 years to avoid favoring the more shade-tolerant species.

Prescriptions involving stocking reduction in precommercial stands should take into account rust hazard and rust status. Grand fir, western hemlock, and western redcedar more effectively suppress *Ribes* than do Douglas-fir, western larch, and pines. Therefore, *Ribes* populations will decline most rapidly in heavily stocked stands with high proportions of grand fir, western hemlock, and western redcedar.

A variety of thinning or cleaning prescriptions may be used to accomplish stocking goals and suppress *Ribes* in young stands. Species composition, stocking, site quality, and *Ribes* population are considerations for design of such prescriptions. For example, high thinning may be used to maintain growth of the best codominants while retaining heavy stocking on the site to suppress *Ribes*. This, then, can be followed in later years by low thinning, if desired, to reduce stocking of intermediate and suppressed crown classes.

If lethal infection rates are high, the imminent mortality of white pine may be sufficient to reduce stocking to, or below, the desired level. Also, thinning or cleaning investments may be jeopardized by subsequent mortality from blister rust infection.

A rust status survey (appendix D) should be made separately or in conjunction with a prethinning or cleaning examination. This will provide necessary information on lethal cankers to develop a proper cleaning or precommercial thinning prescription.

White pines that are crop-tree candidates should be examined carefully for lethal infections, particularly in the basal whorl where cankers often are overlooked.

## Commercial Stands

Foiles (1972) reported 10-year results of a commercial thinning study in western white pine stands on the Clearwater National Forest. He tested growth response and volume production from 87-year-old stands receiving light and moderate high thinning, light and moderate selection thinning, and no thinning. Basal area removed in thinning was 19 percent and 37 percent in light and moderate high thinning, respectively; 19 and 30 percent in light and moderate selection thinning, respectively. Average diameter growth was greatest and mortality was least following moderate high thinning. Selection thinning, particularly moderate intensity, resulted in excessive mortality of residuals. Light crown thinning was the best treatment of harvest-anticipated mortality while maintaining near maximum volume production.

In another study, low thinnings in 60-year-old, primarily white pine stands reduced basal area 25, 50, and 62 percent (Foiles 1955). Most of the trees cut during thinning were submerchantable. Thirty years after thinning, plots that had been reduced 25 and 50 percent in basal area had 22 and 2 percent greater net board foot volume, respectively, than unthinned plots. Low thinning, which reduced basal area by 62 percent, resulted in 16 percent less net board foot volume 30 years later compared with unthinned plots. Based on these results, Foiles recommended that low thinnings to maximize quantity and quality of volume production should reduce basal area by about 25 percent.

Stocking reduction in stands that are more than about 40 years of age is unlikely to result in significant increases in mortality before final harvest.

The time required for new, potentially lethal infections to cause mortality increases as tree diameter increases. For example, an 11.3-inch-d.b.h. tree is expected to survive 17 to 24 years after infection (Buchanan 1938). Before stocking is reduced, rates of new infection generally are low in well-stocked stands older than 40 years because surviving *Ribes* are restricted to open ridgetops and rock outcroppings where sufficient sunlight is available (Moss and Wellner 1953).

The type and intensity of thinning in mature stands can greatly alter rust hazard of sites for subsequent rotations. Refer to appendix G, *Ribes* Ecology and Management, for a discussion of this subject.

# APPENDIX D: RUST STATUS

Rust status refers to a measure of the proportion of white pines that could benefit from pruning or canker excision. This measurement can be used to predict survival times of rust-infected white pines up to about 40 years hence.

## Stands Greater Than 10 Years Old

Stands that are at least 10 years of age but average less than 35 feet in height offer the greatest opportunity for treatment to reduce mortality. A large proportion of the potentially lethal infections often are removable through pruning at this stage. If excision is done it is nearly always in combination with pruning, and gains from the two are additive.

For this size class of trees the rust status model predicts influence of new infections. The trees are still of a size at which new infections can cause significant mortality.

Trees taller than 30 feet may have progressed mostly beyond the stage in which pruning will significantly decrease mortality. But, excision may be even more feasible in trees this size. Individuals are presumably more valuable; stems are larger, allowing for removal of more bark in the excision process without exceeding the tolerable amount of girdle, and chances of new lethal infections are considerably lower. Mortality prediction by the rust status program mortality model for trees greater than 35 feet in height is minimally influenced by new infections.

A rust status sample should include at least 50 to 100 white pines in each stand. Depending on the size of trees, fixed 1/300-acre plots or variable plots giving about 2 percent coverage of the stand are recommended for sampling. Tree height, age, condition (live or dead), total number of cankers on tree, and measurements on the "most lethal" canker are recorded (table 4). The most lethal canker is that which is likely to kill the tree soonest. Priorities for most lethal cankers are:

1. Basal canker, a stem canker of which the lower end is less than 3 inches above ground line (fig. 4B, center of book).

2. Stem canker, a canker more than 3 inches above ground line; in the case of multiple stem cankers, that which has the highest percentage of girdle is measured.

3. Branch canker; the canker closest to the stem is measured.

Additional lethal cankers can be entered into the rust status model to improve accuracy of predictions. Up to 20 lethal cankers can be entered for each tree. Data required for each additional lethal canker will be the same as listed in table 4.

| If the most lethal canker is: | Record |
|---|---|
| stem (fig. 4B&C, center of book) | 1. percentage girdled; recorded to nearest 10 percent. Visually estimated or measured percent of circumference within canker. |
| | 2. diameter of stem at center of canker |
| | 3. within excisable zone - lower edge of canker >3 inches from ground and top edge of canker <6 feet above ground<br>E = within excisable zone<br>NE = not within excisable zone |
| branch (fig. 5A, center of book) | 1. distance from nearest edge of canker to stem |
| | 2. diameter of stem where branch attaches (immediately above whorl) |
| | 3. within prunable zone - branch attached<br><8 feet above ground<br>P = prunable<br>NP = not prunable |

**Table 4**—Rust status data format for stands greater than 10 years of age

| Tree No. | Height | D.b.h. | Age | Condition[1] | Total Cankers | Total Lethal cankers measured | Stem Girdle | Stem Diameter | E[2] | NE[2] | Branch Distance | Branch Diameter | P[3] | NP[3] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Feet* | *Inches* | | | | | *Percent* | *Inches* | | | *Inches* | *Inches* | | |
| 1 | 7.5 | 1.0 | 12 | L | 3 | 1 | | | | | | | | |
| 2 | 9.3 | 1.8 | 19 | L | 2 | 1 | | | | | 9.2 | 2.1 | X | |
| 3 | 8.7 | 1.4 | 15 | D | 7 | 1 | | | | | | | | |
| 4 | 12.9 | 3.4 | 11 | L | 1 | 1 | 60 | 3.3 | X | | | | | |
| 5 | 10.1 | 3.0 | 20 | L | 2 | 0 | | | | | 31.2 | 1.8 | | X |
| : | | | | | | | | | | | | | | |
| : | | | | | | | | | | | | | | |
| 100 | 9.7 | 2.5 | 15 | L | 1 | 1 | | | | | 7.5 | 2.6 | X | |

[1]L = alive; D = dead.
[2]E = excisable; NE = nonexcisable.
[3]P = prunable; NP = nonprunable.

## Five- to Ten-Year-Old Stands

Of major interest in 5- to 10-year-old stands are percentage lethally infected and percentage savable by pruning. Excision will not be possible in trees this small, so stem canker measurement is unnecessary. Trees with stem cankers or branch cankers within 6 inches of the stem are expected to die within 5 years. In addition, all trees with branch cankers between 6 and 24 inches from the stem have high probabilities of dying within 20 years unless those savable through pruning are pruned.

If heavy infection in one year threatens to cause unacceptably high mortality, and if sufficient reduction in mortality is possible through pruning, it may be economically feasible to prune. The value of the white pine component will largely determine the potential benefits of pruning at a young age. *Ribes* reduction may be desirable to prevent recurrence of high levels of lethal infection, or a second pruning may become necessary in a few years.

Mortality prediction for this age class of trees considers both current lethal infection rates and expected new lethal infection rates.

The sample includes 50 to 100 white pines 5 to 10 years of age. Recorded are condition of each tree (live or dead) and the category, (nonlethal-canker >24 inches from stem, prunable-6 to 24 inches from stem, or nonprunable-6 inches from stem or present in stem) of the most lethal canker. Table 5 illustrates a suggested data collection format. If pruning is not considered a treatment alternative, the trees can be recorded as infected or noninfected without regard to position of cankers. Fixed 1/300-acre plots on a grid providing even coverage of the stand are recommended for sample tree selection.

**Table 5**—Rust status data format for 5- to 10-year-old stands

| | | Most lethal canker[2] | | |
|---|---|---|---|---|
| Tree No. | Condition[1] | <6 inches or stem | 6 to 24 inches | >24 inches |
| 1 | L | | X | |
| 2 | L | | X | |
| 3 | D | X | | |
| 4 | L | | | X |
| ⋮ | | | | |
| 100 | L | | X | |

[1]L = alive; D = dead.
[2]Distance from nearest margin of branch canker to stem.

# APPENDIX E: PRUNING AND EXCISING

## Pruning

Numerous guides for pruning white pines to control blister rust have been published over the years. Most of these were developed specifically for eastern white pine in the Lake States (Brown 1972; Nicholls and Anderson 1977). More recently, Hunt (1982) has developed guidelines for pruning western white pine in British Columbia, Canada. Recommended procedures have varied from single to double and even biennial pruning, and beginning in trees as small as 1 foot in height (Weber 1964).

Basal and lower stem cankers are most often the cause of mortality of blister rust-killed western white pines. These infections occur when trees are small, generally 2 to 5 feet in height. In trees this size, the lethal infection zone (fig. 4A) includes branches on the lower bole.

If stands are to be pruned only once, trees should be at least 10 to 20 years old, which allows selection of the best crop trees. Specific timing of pruning projects depends largely on the position of potentially fatal branch cankers. Decisions to prune or excise should always be preceded by a rust status survey (appendix D) to ascertain the proportions of trees uninfected, prunable, excisable, and untreatable in the stand.

A single pruning to a height of 8 feet or the lower 50 percent of the tree height (whichever is less) is recommended for Northern Region western white pine. This procedure should be accompanied by pathological pruning (removal of cankered branches only) of any infected branches within reach above the standard pruning height. Pruning branches to a set height has been shown to be more effective and, in some cases, less costly than pruning only infected branches (Stewart 1957). In pathological pruning, time is spent searching branches for infection, and still many cankers go undetected. Experience has shown that about 20 percent of the single-pruned trees will still be fatally infected (Stewart 1957). This figure may be reduced somewhat through excision at the time of pruning. But most of this mortality is due to infections that had been judged prunable but in fact were not prunable. You should expect about 20 percent fewer white pine to reach rotation than have been treated.

Where stocking is marginal, double pruning may be justified. Hunt (1982) offered recommendations for forests in British Columbia. He suggested a first pruning when trees are 8 feet tall, pruning to a height of 4 feet, with pathological pruning of higher infections. A second pruning would be carried out when trees were 13 feet tall, pruning to 8 feet, with pathological pruning above this height. A larger proportion of trees can be saved in the earlier pruning; however, new infections may threaten your investment unless they are removed in a second pruning or hazard is reduced through *Ribes* suppression.

Only white pines and all white pine crop trees should be pruned whether they appear to be infected or not. If excision is not part of the treatment, pines with only prunable cankers should be pruned, those with no stem cankers or nonprunable branch cankers. If excision is planned as well, all cankers should be prunable or excisable on selected trees.

Pruning to 8 feet can be accomplished using pruning shears with handles 2 feet long. Pole pruners may also be used to remove infections higher in the crowns; however, they are generally slower and more difficult to maneuver. They may add significantly to costs.

Live branches of the basal whorl often are partially buried in duff and vegetation and may be overlooked. Crews should be instructed to check carefully for basal branches.

Branches should be cut flush with the branch collar (fig. 6). White pine has very little tendency to develop decay from wounds, so wound treatment is not recommended.

## Excising

Canker excision consists of cutting away all diseased bark and cambium or cutting a channel to the sapwood between diseased and healthy tissue (fig. 4D). This is best accomplished from mid-April through early June when cankers (fig. 4C) are most visible and bark slips easily while cutting. Excisable cankers are those that girdle no more than 50 percent of the circumference and with the upper edge of infection no more than 6 feet from the ground. This includes the discolored area beyond the obvious edge of the canker (figs. 4E and 4F).

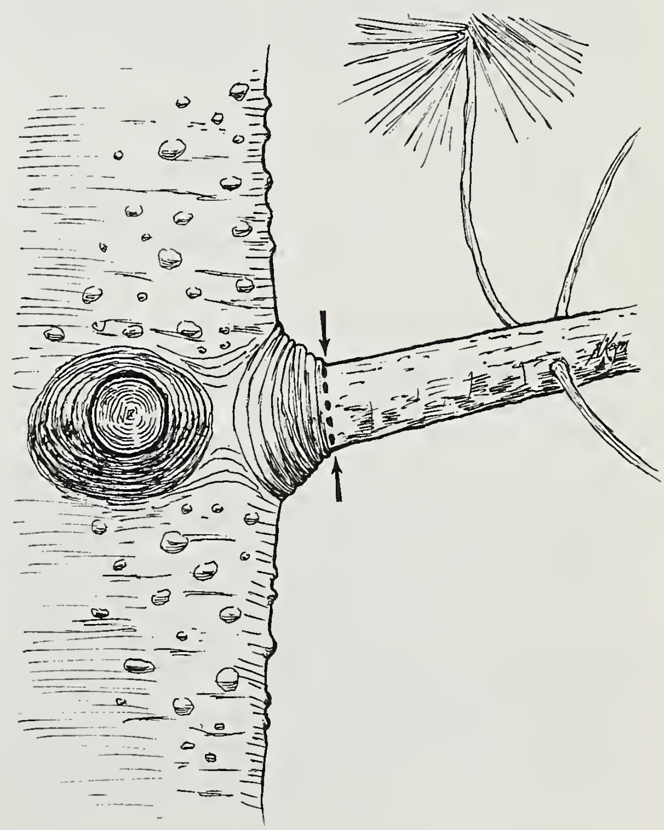

**Figure 6**—Branches should be pruned flush with the branch collar (arrows).

Branch cankers within 6 inches of the bole are removed by pruning the branch, followed by excising the bole around the branch collar 2 inches from the outer edge of the collar.

We recommend using a tree scribe with a ½-inch blade (fig. 4D). The inner edge of the channel should be 2 inches from visible discoloration. The channel must be scribed continuously all the way around the canker and fully to the sapwood. Cambial "bridges" may allow passage of the fungus beyond the groove. Basal cankers, which are those with the lowest edge less than 3 inches above ground (fig. 4B), are considered nonexcisable because of difficulties in performing the excision. This does not mean it cannot be done, but it would add unreasonable expense to treat such trees.

Excision should be preceded by pruning to standard height or one-half tree height. Trees with more than one stem canker should not be considered for excising.

Even for an inexperienced person, it should take less than a minute to complete the excision of a canker.

## Additional Tips

Specific design of pruning and excising projects will vary by Districts and by situations. Choose the one most expedient for your project. Consider these tips: (1) If you are having difficulty detecting the leading edge of diseased tissue, try wetting the bark with water in a spray bottle. (2) Crop trees should be selected and marked before crews begin pruning and excising. (3) Both pruning and excising should be performed at one time by one person before moving on to the next tree. This saves repeating the inspection process to find stem cankers.

## Costs

Few reports of pruning time and costs are available from western white pine experience. Foiles (1956) reported length of time required for pruning white pines to 17 feet using hand and pole saws. An average of one person-day was required to prune 128 trees to an average of 9.11 feet using handsaws. Pruning time for pole saws was considerably higher. These data included administrative time for supervision and marking as well as total crew time involving travel between trees, rest periods, and other delays.

Kelly Creek Ranger District, Clearwater National Forest, completed a pilot test of pruning and excising in 1983. They treated 86 trees/person-day by pruning or pruning and excising. The trees averaged 8 feet in height and were pruned to one-half their height. They treated 69 trees/acre for a cost of $63.36/acre or $0.92/tree. Costs included wages, transportation, tools, and miscellaneous administrative costs. The crews used pruning shears with handles 2 feet long for pruning and tree scribes for excising.

A pruning and excision project was completed in 1985 by the Palouse Ranger District of the Clearwater National Forest (Hagle and Grasham 1988). White pine plantations 15 to 18 years old were treated. Treated trees averaged 4.3 inches d.b.h. and 15 feet in height. They were pruned to one-half their height, with additional pathological pruning. Excision of a canker was required in 37 percent of the pruned trees. Eighty-eight acres, averaging 103 treated trees per acre, were treated at a cost of $56.82/acre. This cost included supplies, travel, wages, and benefits. The project required 45 person-days (0.51 person-day/acre) to complete. Nearly half of this time was in travel to and from the job. In terms of actual time on the job (excluding travel and training time), 2 person-hours were required to treat each acre.

## APPENDIX F: SEED SOURCES

Planting stock recommendations are based on tested survival rates for the various progeny types now available. Phenotypically resistant trees from natural stands with high average infection rates were first selected (Phase I) and tested in 1950-57. New selections and tests were made again in 1967 (Phase II) and continue through the present. The percentage of offspring that survived artificial inoculation after 2 years was determined for each of these parents. Parent trees that had produced higher than average percentage of resistant progeny were considered to have general combining ability (GCA) (Steinhoff 1971). Those with lower than average resistant progeny were considered not to have general combining ability and were designated nonGCA. Various crosses with surviving progenies of the $F_1$ generation were made through controlled and open pollination (OP) (table 6). Progenies from these crosses were field tested and relative infection rates were measured.

Greatest resistance is obtained from the $F_2$ progeny (Bingham and others 1973) (table 6). These should be reserved for sites requiring the highest level of resistance for plantation success. $F_1$ x GCA parent backcross has a comparable overall number of infections in stands but a higher percentage of trees will be infected than will those of the $F_2$ stock.

**Table 6**—Derivation of recommended stock types

| Designation | Derivation |
|---|---|
| Wild | Generally from natural regeneration where seed tree selection was not made. |
| Phenotypically OP | Selected seed trees or seed collected from selected naturally grown trees. |
| NonGCA OP | Open pollinated seed from trees known not to have general combining ability. |
| GCA OP | Open pollinated seed from trees known to have general combining ability. |
| GCA x nonGCA (Not available)[1] | Controlled pollinated seed from trees known to have general combining ability crossed with trees known not to have general combining ability. |
| $F_1$ | Controlled pollinated seed from cross between two trees known to have general combining ability. |
| $F_1$ x GCA parent (Not available)[1] | Controlled pollinated seed from backcross between $F_1$ and GCA parent. |
| $F_2$ | Controlled pollinated seed from cross between two or self of one, $F_1$ trees. |

[1]Seed from these sources has been tested but is not generally available for operational use because the crosses are made through controlled pollination.

$F_1$ and GCA x nonGCA stock have considerably less resistance than the previous two types but will have reasonably good survival rates on moderate hazard sites. GCA OP falls about midway between the $F_1$ or GCA x nonGCA and nonGCA OP. NonGCA OP is about the same as open-pollinated, phenotypically resistant, untested trees found in heavily infected stands.

Differences in infection rates between wild seedlings (those of unknown parentage), and progeny of phenotypically resistant, untested trees is minimal except in lowest hazard sites. Here, the progeny of phenotypically resistant trees show better survival.

Phenotypically resistant trees that have been tested in Phases I and II of the white pine tree improvement program (Franc 1982) should be used as operational seed sources by districts. These will provide GCA OP and nonGCA OP seed (table 7). Most white pine-producing Districts will have many trees that were tested among the first 400 screened in Phase I of the program. Many of these trees are the ortets for the grafted white pine seed orchard in Sandpoint, which now produces $F_1$ seed.

**Table 7**—Genetic makeup of current seed sources covered in USDA Forest Service Northern Region Handbook (USDA FS 1984)

| Seed source | Genetic makeup |
|---|---|
| Seed collection stand[1] | Wild type |
| Selected individual tree | Wild type,<br>Phenotypically resistant |
| Seed production area[2] | Wild type,<br>Phenotypically resistant |
| Test plantation[3] | Mixed: approximately equivalent to $F_1$ |
| Progeny tested wild trees | NonGCA x OP,<br>GCA x OP |
| Seed orchard | $F_1$ - Sandpoint Seed Orchard |
| | $F_2$ - Moscow Arboretum,<br>Coeur d'Alene Seed Orchard,<br>Lone Mountain Seed Orchard |

[1]Not an approved seed source for USDA Forest Service, Northern Region.

[2]Seed production areas that do not qualify for selection of phenotypically resistant parent trees—stand has not experienced 80 to 90 percent mortality of western white pine due to blister rust—should be considered to produce wild-type seed. Phase II plus trees that have not been progeny tested are considered to be phenotypically resistant seed sources.

[3]USDA Forest Service test plantations consist of a variety of stock types ranging from wild-type (control) to $F_2$ (Moscow Arboretum seed). Progeny tests from these seed mixtures have shown the test plantations to produce approximately equivalent resistance to $F_1$ stock from the Sandpoint Seed Orchard. Approved plantations are Canyon Creek on the Priest River Experimental Forest, Fernwood and Merry Creek on the Idaho Panhandle National Forests (St. Maries Ranger District), and Elk River and Hog Meadows on the Clearwater National Forest (Palouse Ranger District).

# APPENDIX G: *RIBES* ECOLOGY AND MANAGEMENT

*Ribes viscosissimum*, and *R. lacustre* are the *Ribes* species of greatest concern to white pine managers in the Northern Region. They are "upland" species, dispersed throughout white pine stands, as compared to those limited to creek bottoms or other wet areas. Together they constituted 93 percent of the *Ribes* plants eradicated in this Region from 1923 through 1950 (Moss and Wellner 1953). Their site requirements correspond well to those of western white pine (appendix A). Both *Ribes* species survive and reproduce best on moderately cool, moist, north and east exposures. Both also will grow on warmer, drier slopes, although *R. viscosissimum* does better than *R. lacustre* on these sites. *Ribes viscosissimum* is most abundant in stands with western larch, lodgepole pine, Douglas-fir, Engelmann spruce, subalpine fir, and white pine. It is more readily suppressed by competition for sunlight in stands with major components of grand fir, western hemlock, and western redcedar. *Ribes lacustre* survives better than *R. viscosissimum* in stands of the latter type because of its greater shade tolerance. *Ribes lacustre* requires only 25 percent of full sunlight as compared to 40 percent for *R. viscosissimum.*

*Ribes* seed production begins at 3 to 5 years of age and continues annually as long as the plant survives. *Ribes lacustre* is also capable of reproducing by layering. Seeds from *Ribes* plants are heavy, and dispersion from the mother plant is limited. If undisturbed, viable seed remains stored in duff for more than 200 years. Cool, moist duff commonly found under the closed canopy of a mature forest provides ideal storage conditions for prolonged *Ribes* seed viability. Exposure of mineral soil by fire or by mechanical disturbance of the duff will stimulate *Ribes* seed germination. Incomplete exposure of the mineral soil can stimulate germination, but survival of germlings is low if a partial duff layer is still present.

## Management

**Silvicultural Control**—Controlling light regimes to regulate *Ribes* populations can be a consideration in commercial stands. Moderate cutting that permits 30 to 50 percent of full sunlight to the ground can be effective in reducing rust hazard through *Ribes* suppression. Following logging, an average of 200 *Ribes* seeds per acre can be expected to germinate, and about 20 seedlings may become established (Moss and Wellner 1953). These figures vary considerably among sites, depending on site histories. Most of the young *Ribes* plants will receive insufficient sunlight for survival under the forest canopy, and within a few years following thinning they will have died. Most of the residual, ungerminated seed is devitalized by increasing temperature and decreasing moisture in the duff. Surviving bushes will be localized in openings such as logging roads or slash-burning areas. When the remainder of the stand is harvested, the *Ribes* population—rust hazard—should be much reduced compared to the potential hazard prior to cutting.

Increasing solar radiation enough to devitalize stored *Ribes* seed but not enough for prolonged support of *Ribes* plants requires considerable planning and control. Wellner (1948) found that 30 to 40 percent of the basal area in a well-stocked, mature stand can be removed to achieve the required light regime (30 to 50 percent of full sunlight). If canopies are not sufficiently opened, only a small proporton of the stored *Ribes* seed is devitalized. Few *Ribes* from seeds that germinate following stocking reduction of less than 30 percent of the basal area of well-stocked, mature stands survive to become established. Therefore, such cuttings neither increase nor greatly decrease site rust hazard.

Stocking reductions that remove more than 40 percent of the volume from well-stocked, mature stands may provide ideal conditions for *Ribes* reproduction. Light shading improves *Ribes* seedling survival and seed storage conditions. Moss and Wellner (1953) reported an average of 1,542 *Ribes* seeds per acre germinating in 12 such heavily cut stands. Of these germlings, 1,472 survived to become established.

Moderate intensity, high or selection thinnings in commercial stands, and some applications of shelterwood regeneration methods provide opportunities for rust hazard reduction. Refer to appendix C for a discussion of stocking reduction in white pine stands.

A preparatory shelterwood cut that reduces basal area by 30 to 40 percent can reduce rust hazard. At least 5 years should be allowed between this and the next cut, generally a seed cut, to allow time for seed devitalization and shading death of germinated *Ribes* plants.

Minimizing duff disturbance during harvest can greatly reduce *Ribes* seed germination. Winter logging has resulted in 95 percent fewer *Ribes* seedlings than summer logging (Moss and Wellner 1953). Most ungerminated seeds will devitalize within about 3 years because storage conditions are changed by raising temperature and decreasing moisture in the duff. If slash is piled and burned before *Ribes* seed devitalization occurs, seed will germinate along the periphery of burn sites. Full sun produces the most rapid devitalization. Increasing shade prolongs the period of seed viability. Under full shade, as occurs with light stocking reductions, seed viability can be extended up to 25 years.

## Direct Control

Total elimination of *Ribes* should not be attempted; instead, aim to reduce the population to levels that suit resistant white pine stock types available.

*Ribes* bushes are most effectively eradicated by means of a claw mattock developed for this purpose. The root crown and about 4 inches of root below the crown must be removed to assure the plant will not resprout. This method is not totally effective due to frequent resprouting of improperly pulled plants and crews missing plants (USDA FS 1959a).

More efficient is chemical control of *Ribes* (Offord and others 1958). Spot spraying using backpack sprayers is best suited to sites with clumped *Ribes* distribution. Miller (1984) was able to kill as much as 89 percent of established 2-year-old *R. viscosissimum* plants on a white pine site applying chemicals from a backpack sprayer. Broadcast spraying, generally from helicopters, will be more efficient where *Ribes* populations are heavy and disperse (DeJarnette 1953). Efficiency of chemical control varies with the compound used and application rate (Miller 1984; Miller and Kidd 1983), physiological conditions of *Ribes* (Miller 1984), weather and site factors, and method of application. Assistance of a qualified pesticide applicator is necessary for any spray project.

# APPENDIX H: *RIBES* POPULATION DETERMINATION

*Ribes* population surveys are generally conducted to determine the white pine type appropriate for regeneration or the need for *Ribes* population reduction. Among conditions where *Ribes* surveys may be desirable are (1) clearcut or burned areas that have had sufficient time for *Ribes* to become established (3 years) and are intended for white pine regeneration; (2) young plantations or natural stands that have sufficiently high infection rates to indicate a need to reduce *Ribes* populations; (3) open stands where natural openings, tree mortality, or partial cutting have resulted in conditions favorable for *Ribes* and white pine is considered for regeneration.

Knowledge of exact *Ribes* populations is not necessary. Five *Ribes* population levels are used to determine relative rust hazards (table 3).

## *Ribes* Identification

Hitchcock and Cronquist (1976) list 30 species of *Ribes* in the Pacific Northwest. The upland species are the most uniformly distributed and thus are considered most important for *Ribes* population determination species in the white pine type. In northern Idaho and western Montana, *R. viscosissimum* and *R. lacustre* are the most common of the upland species.

*Ribes* plants have simple leaves as compared to the compound leaves of rose (*Rosa* spp.), or raspberry (*Rubus* spp.) (fig. 5B, center of book).

*Ribes* can be confused with thimbleberry (*Rubus parviflorus*) and ninebark (*Physocarpus malvaceous*). The latter two species have stipules at the junction of the petiole and stem; *Ribes* species have no stipules.

*Ribes lacustre* (fig. 5C) (prickly currant) has shiny green leaves with well-divided lobes. Stems are brown with many spines or prickles, particularly at nodes.

*Ribes viscosissimum* (fig. 5D) (sticky currant) has pubescent, glandular (sticky) leaves, which have a spicy odor when crushed. Lobes of leaves are broad, rounded. Stems are spineless.

## Survey Methods

*Ribes* populations generally peak 3 or 4 years following site disturbance. Bushes are larger and easier to detect 4 to 10 years after site disturbance. Small *Ribes* plants are easily missed, especially where populations are low.

*Ribes* population determinations can be incorporated into stand examinations by counting *Ribes* plants that fall, in any part, within the fixed-radius plot. Plots 1/100-acre (11.9-foot-radius circular plots) or 1/300-acre (6.8-foot-radius circular plots) in size may be used to tally *Ribes* bushes during stand examinations.

Plots should be on a grid covering the stand evenly. If plots are established at 5-chain intervals along a compass line with 10-chain intervals between parallel lines (USDA FS 1985), 1/100- and 1/300-acre plots give about 2 percent and 1 percent coverage, respectively.

If the *Ribes* survey is not conducted in conjunction with stand examination, a continuous strip method may be used (USDA FS 1959b). A 16-foot-wide continuous strip is run along a compass line. All *Ribes* plants encountered in a 1-chain interval along the strip are tallied. We recommend maintaining a map of strips. This will aid in identifying higher risk areas within a stand where *Ribes* distribution is clumpy.

Strip interval is 4, 8, or 16 chains depending on density and distribution of *Ribes*. Intervals of 16 chains may be sufficient for large units with large, evenly distributed *Ribes* populations. The entire stand should be covered first in 16-chain intervals. Lengths of strips are measured by pacing. One acre is equal to a 16-foot-wide, 41.25-chain-long strip. If *Ribes* plants are infrequent in the initial survey, go back and fill in by offsetting 8 chains and running an additional strip between each of the first strips. Intervals of 4 chains may be used where stands have very few *Ribes* plants or highly clumped distribution of *Ribes*. Intervals of 16, 8, and 4 chains give about 2, 3, and 5 percent coverage, respectively.

## Potential *Ribes* Population Estimates

Estimating potential *Ribes* populations for uncut sites is less definitive than surveying existing populations and requires interpretation of many factors. Moss and Wellner (1953) set forth guidelines to aid in estimating potential *Ribes* populations for uncut sites. Their guidelines are presented below. These can be used to separate two general ranges of *Ribes* populations—low and high. Sites judged to have low *Ribes* potential by this method are considered equal to rust hazard level 2. Based on results of *Ribes* surveys conducted from 1932 to 1966, (published in annual reports of the blister rust control program of the Northern Service Region of the Forest Service) sites with high *Ribes* potential should be considered to have rust hazard level 5 if located in the St. Joe or Clearwater areas of Idaho, and level 4 outside these areas. Although these broad categories are less than satisfactory, they are better than having no rust hazard estimate for selecting appropriate white pine planting stock.

Guidelines from Moss and Wellner (1953) are as follows:

*Populations Averaging Less Than 25 Bushes Per Acre (Rust Hazard Level 2)*

1. Stands on south and west slopes that originated after two or more fires occurring less than 20 years apart.

2. Stands that originated after two or more fires which together completely consumed the organic mantle down to the mineral soil.

3. Stands overmature, more than 200 years old, fully stocked since inception, and composed largely of western hemlock and western redcedar.

4. Stands with a high proportion of western larch, lodgepole pine, ponderosa pine, and Douglas-fir growing in shallow soil with a substratum of sand, gravel, or rock.

*Populations Averaging More Than 25 Bushes Per Acre (Rust Hazard Level 4 or 5)*

1. Stands that originated after a single burn.

2. Stands on north and east exposures that originated after two or more natural fires occurring more than 10 years apart.

3. Stands that originated after one or more fires, none of which completely consumed the organic mantle down to the mineral soil.

4. Open-grown stands on north and east exposures with inadequate cover to suppress *Ribes* bushes or prevent their continued seeding.

5. Crests of prominent ridges from which *Ribes* bushes are rarely suppressed by forest cover.

6. Heads of drainages where streams finger out over upland slopes and create habitats more favorable for shrubs than for trees.

These guidelines can be enhanced for white pine stock type selection by integrating observations of *Ribes* populations from surrounding sites with similar histories, or from road cuts, open ridgetops, or other features which prolong upland *Ribes* survival.

Surveys of *Ribes* seeds in forest soil and duff may be of considerable utility in estimating potential (Quick 1956). But techniques have not been developed sufficiently for operational use.

Hagle, Susan K.; McDonald, Geral I.; Norby, Eugene A. 1989. White pine blister rust in northern Idaho and western Montana: alternatives for integrated management. Gen. Tech. Rep. INT-261. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 35 p.

This report comprises a handbook for managing western white pine in northern Idaho and western Montana, under the threat of white pine blister rust. Various sections cover the history of the disease and efforts to combat it, the ecology of the white pine and *Ribes*, alternate host of the rust, and techniques for evaluating the rust hazard and attenuating it. The authors advocate an integrated control strategy based on local stand conditions. Options include planting resistant strains of pine, excising cankers, and chemical, mechanical, and silvicultural control of *Ribes*.

KEYWORDS: silviculture, timber management, plant pathology, *Ribes* spp., forest genetics, reforestation, *Pinus monticola*

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